ENGINEERING 4020

MARINE FLUID DYNAMICS

QUIZ #1

The scaling laws for pump pressure, flow and power are:

$$C_P = P/[\rho N^2 D^2] \quad C_Q = Q/[ND^3] \quad C_{\mathbf{P}} = \mathbf{P}/[\rho N^3 D^5]$$

Outline briefly the derivation of these laws. Discuss briefly the implications of the laws for pump design. [20]

A 10m long pipe separates a pump and a water storage tank on a ship. The tank pressure is 5 BAR gage. The flow speed in the pipe is 0.5m/s. The wave speed for the pipe is 1000m/s. The density of water is 1000kg/m^3. There is a valve just downstream of the pump. Describe what happens in the pipe when the valve is suddenly shut. Use P versus x and S versus x plots to illustrate your answer. [20]

Identify on the formula sheet the critical speed equation for each of the following: (1) vortex shedding resonance (2) galloping instability (3) tube bundle vibration (4) pipe flow buckling (5) pipe flow whip (6) panel flutter. Write brief notes on the flows in each case. [40]

Identify on the formula sheet the equations governing turbulent hydrodynamic flows. Describe briefly how these equations can be solved using CFD and time stepping. [20]

$$C_P = P \;/\; [\rho N^2 D^2] \qquad C_Q = Q \;/\; [N D^3] \qquad C_{\mathbf{P}} = \mathbf{P} \;/\; [\rho N^3 D^5]$$

$$C_{\mathbf{P}} = \mathbf{P} \;\mathbf{/}\; [\rho\; S^3/2 \;\; A] \qquad C_{\mathbf{S}} = r\omega \;/\; S$$

$$C_D = \mathbf{D} \;/\; [[\rho S^2/2]\; A] \qquad Re = SD/\nu \qquad Fr = S/\sqrt{[gL]}$$

$$T = D/S \qquad C_T = \mathbf{T}/T \qquad St = T/\mathbf{T}$$

$$S^2 = [\; EI/[\rho A]\; \pi^2/L^2 + T/[\rho A] - P/\rho \;]$$

$$S = [4 + 14\; M_\circ/M]\; S_\circ$$

$$S_\circ = \sqrt{[[EI]/[M_\circ L^2]]} \qquad M_\circ = \rho A$$

$$|\Delta P| = \rho\; a\; |\Delta S| \qquad a = \sqrt{[\mathbf{K}/\rho]}$$

$$\mathbf{K} = K \;/\; [1 + [DK]/[Ee]]$$

$$S^2 = [Tk^2 + Dk^4 + K/w + \rho_B g - \rho_T g]\; *$$

$$[\rho_T/k + \rho_B/k + \sigma] \;/\; [\rho_B \rho_T + \sigma \rho_T k]$$

$$S = S_\circ\; M/M_\circ\; \zeta\; a \qquad S_\circ = D/\mathbf{T} \qquad M_\circ = \rho D^2$$

$$S = \beta/\mathbf{T}\; \sqrt{[M\delta/\rho]} = \beta S_\circ\; \sqrt{[\delta M/M_\circ]}$$

$$S = D/[\mathbf{ST}] \qquad \mathbf{T} = \mathbf{T}$$

$$\mathbf{T}_n = [2L/n]\; \sqrt{[m/T]}$$

$$\mathbf{T}_n = [L/n]^2\; [2/\pi]\; \sqrt{[m/EI]}$$

$$\mathbf{T}_n = 2\pi L^2/K_n\; \sqrt{[m/EI]}$$

$$\rho \ (\partial U/\partial t + U\partial U/\partial x + V\partial U/\partial y + W\partial U/\partial z) + A = - \partial P/\partial x$$

$$+ \ [\partial/\partial x \ (\mu \ \partial U/\partial x) + \partial/\partial y \ (\mu \ \partial U/\partial y) + \partial/\partial z \ (\mu \ \partial U/\partial z)]$$

$$\rho \ (\partial V/\partial t + U\partial V/\partial x + V\partial V/\partial y + W\partial V/\partial z) + B = - \partial P/\partial y$$

$$+ \ [\partial/\partial x \ (\mu \ \partial V/\partial x) + \partial/\partial y \ (\mu \ \partial V/\partial y) + \partial/\partial z \ (\mu \ \partial V/\partial z)]$$

$$\rho \ (\partial W/\partial t + U\partial W/\partial x + V\partial W/\partial y + W\partial W/\partial z) + C = - \partial P/\partial z - \rho g$$

$$+ \ [\partial/\partial x \ (\mu \ \partial W/\partial x) + \partial/\partial y \ (\mu \ \partial W/\partial y) + \partial/\partial z \ (\mu \ \partial W/\partial z)]$$

$$\partial P/\partial t + \rho \ c^2 \ (\partial U/\partial x + \partial V/\partial y + \partial W/\partial z) = 0$$

$$\partial F/\partial t + U\partial F/\partial x + V\partial F/\partial y + W\partial F/\partial z = 0$$

$$\partial k/\partial t + U\partial k/\partial x + V\partial k/\partial y + W\partial k/\partial z = T_P - T_D$$

$$+ \ [\partial/\partial x \ (\mu/a \ \partial k/\partial x) + \partial/\partial y \ (\mu/a \ \partial k/\partial y) + \partial/\partial z \ (\mu/a \ \partial k/\partial z)]$$

$$\partial \varepsilon/\partial t + U\partial \varepsilon/\partial x + V\partial \varepsilon/\partial y + W\partial \varepsilon/\partial z = D_P - D_D$$

$$+ \ [\partial/\partial x \ (\mu/b \ \partial \varepsilon/\partial x) + \partial/\partial y \ (\mu/b \ \partial \varepsilon/\partial y) + \partial/\partial z \ (\mu/b \ \partial \varepsilon/\partial z)]$$

$$\partial M/\partial t = N \qquad M_{NEW} = M_{OLD} + \Delta t \ N_{OLD}$$

$$T_P = G \ \mu_t \ / \ \rho \qquad D_P = T_P \ C_1 \ \varepsilon \ / \ k$$

$$T_D = C_D \ \varepsilon \qquad D_D = C_2 \ \varepsilon^2 \ / \ k$$

$$\mu_t = C_3 \ k^2 \ / \ \varepsilon \qquad \mu = \mu_t + \mu_l$$